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THE HEADS OF A COURSE of LECTURES IN *Experimental Philosophy.*

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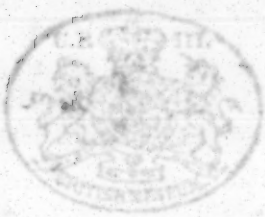

MECHANICS.

1. THE uſes of experiments in natural Philoſophy.

2. Several kinds of force, by which bodies act upon each other.

3. Glaſs planes attract each other.

4. They attract water, and raiſe it between them.

5. A Line drawn along the ſurface of the water, when the planes are nearer at one end than at the other, is an hyperbola.

6. Other fluids will aſcend along theſe planes inclined to each other, and to the horizon.

7. The attraction varies according to different laws, when the planes are dry, and when wetted with the fluid, which riſes between them.

8. Metals cohere ſo ſtrongly by attraction, as to ſuſtain great weights.

9. The force, by which the magnet draws iron, is not ſtopped by the interpoſition of other bodies.

10. Iron or ſteel gains the virtue of a magnet, by being rubbed upon it;

11. And loſes it again, by being rubbed in the contrary direction:

12. The ſame virtue is given it in ſeveral other ways.

13. The force of the magnet's attraction at different diſtances.

14. Mercury is attracted by gold or ſilver, and repelled by iron.

15. Electrical bodies attract and repel others.

16. Their forces paſs through the denſeſt bodies,

17. And may be communicated to all bodies not of themſelves electric.

18. This attraction is perceived at great diſtances;

19. It is attended with ſparks of fire coming from all parts of the body, to which the electricity is communicated.

20. The cauſes hitherto aſſigned for theſe actions of the parts of matter upon each other, are hypothetical and inſufficient.

21. There are a kind of glaſs bubbles, any part of which being broken off, the whole burſts into very ſmall pieces.

22. Some account may be given of this phænomenon from the principles hitherto explained.

23. Even the denſeſt bodies abound with pores.

24. The conſtituent parts of all bodies are exceedingly minute.

25. From hence it happens that fluids will inſinuate themſelves into all bodies, and that ſometimes a mixture of two fluids ſhall be leſs in bulk, than when they are ſeparate.

26. Motion is either abſolute or relative.

27. The velocity of an uniform motion is meaſured by the ſpace it deſcribes in a given time.

28.

28. The quantity of motion in any body is meaſured by its velocity and quantity of matter jointly.

29. Equal forces produce equal quantities of motion in bodies of different magnitudes.

30. The laws of motion cannot be proved by ſingle experiments, but are general rules founded upon continual obſervations. The rules are theſe:

31. The direction and quantity of the motion in any body are never altered but by ſome external cauſe;

32. Nor is the direction or quantity of any motion altered, when the whole or any part of it paſſes out of one body into another.

33. No motion is ever produced in any direction, without another equal to it in the oppoſite direction.

34. When a body is at once impelled by two forces, whoſe directions and quantities are given, the direction and velocity of the body may be known.

35. From hence the directions and quantities of three forces may be determined, which acting upon the ſame body, will keep it at reſt.

36. Two forces acting upon the arms of a balance or lever are in æquilibrio, when they are reciprocally as the perpendicular diſtances of the lines of their directions from the center.

37. It is of no conſequence upon what point in the line of its direction the force acts.

38. If there is a greater number of forces, the æquilibrium is, when their quantities being multiplied

tiplied into their reſpective diſtances, the ſums of the products on each ſide the center are equal.

39. Theſe rules are applicable to bent and compound levers, as alſo to ſcales, ſteelyards, and other inſtruments of that kind.

40. The methods by which a balance becomes uſeleſs or deceitful.

41. In the wheel and axle the æquilibrium is, when the force applied to the wheel, is to that applied to the axle, as the radius of the axle, to that of the wheel.

42. The fuſee of a watch may be ſo adjuſted to the decreaſing force of the ſpring while it expands itſelf, that it ſhall act always with the ſame ſtrength upon the wheels.

43. If a body is ſuſpended with a ſingle pully, the force equals half the weight.

44. If there are 2, 3, 4 or more pullies, each of which has a ſeparate ſtring, the force is to the weight as 1 to 4, 8, 16, *&c.*

45. The difference between the weight and force is ſuſtained by the fixed ſtrings.

46. If the pullies all communicate with one another, the force muſt be to the weight, as 1, to the number of the ſtrings at the lower pullies.

47. When a body is ſuſtained upon an inclined plane, the force is to the weight, as the ſine of the inclination of the plane, to the ſine of the angle, which the direction of the force makes with a perpendicular to the plane.

48. To ſuſtain a given body upon a given plane with the leaſt force poſſible, the direction of the force muſt be parallel to the plane.

49. The force will then be to the weight, as the height of the plane to its length.

50. When two bodies reſt upon inclined planes of the ſame height, and ſuſtain each other, their weights are to each other, as the lengths of the planes, upon which they reſt.

51. When two forces perpendicular to the ſides of a wedge are ſuſtained by one perpendicular to the back, the latter is to the ſum of the two former, as the back of the wedge, to the ſum of the ſides.

52. When the direction of the forces acting upon the ſides is parallel to the back of the wedge, the proportion of each of theſe to the third force is not the ſame, as that of the height of the wedge, to the back.

53. The experiments, made to prove this proportion to be juſt, are not applicable to this caſe.

54. The difficulties concerning one caſe of the lever, which is generally mentioned as a paradox, ariſe from a miſtake of the ſame nature.

55. In the ſcrew the æquilibrium is, when the force is to the weight, as the height of one ſpire, to the circumference, which the power deſcribes.

56. In machines compounded of two or more ſimple ones, the forces, which ſuſtain each other, when applied to the different parts, may be determined by the foregoing rules;

57. Or by this general principle, that the æquilibrium is always, when the forces are to each other

other reciprocally, as their velocities, eſtimated in the lines of their directions.

58. No machine can be ſo contrived, that by the action of the parts upon each other, its motion ſhall be made perpetual.

59. No force acting upon the parts of a machine, and upon them only, can give the whole a motion in one direction.

60. This obſervation is not contradicted by the inſtance of carriages, which are ſo contrived, as to be moved forward by the perſons, who ſit in them.

61. Machines never leſſen the whole force neceſſary to perform any work, but are generally uſed either to diminiſh the force applied at once by lengthening the time, or to ſhorten the time by increaſing the force applied at once.

62. In the rules here given no regard is had to the weight of the machine, or the friction of its parts, when they move over each other.

63. The reſiſtance ariſing from friction cannot eaſily be determined by general rules, becauſe it depends upon a variety of circumſtances, ſuch as the materials of the machine, the ſhape of its parts, the force acting upon it, *&c.*

64. One kind of friction depends chiefly upon the force, with which the ſurfaces are preſſed together, and not upon their breadth.

65. To leſſen the reſiſtance ariſing from friction, wheel carriages are uſed.

66. The larger the wheels are the more is this reſiſtance diminiſhed.

67.

67. The direction in which ſuch carriages may be drawn with the leaſt force, is parallel to the plane they move along.

68. There are ſeveral mechanical ways of finding the center of gravity of one or more bodies.

69. From them will appear the reaſon of ſeveral experiments, in which bodies ſeem to move, or to be ſuſtained, contrary to the laws of gravity.

70. By conſidering the ſituation of the center of gravity, it may be determined in what caſes a body will ſlide, roll, fall, or continue at reſt.

71. To ſuſtain the center of gravity of one or more bodies, a force muſt be applied equal to the weight of the whole.

72. A body falling or riſing either perpendicularly, or along an inclined plane, is accelerated or retarded uniformly by the force of gravity.

73. This force is proportional to the quantity of matter.

74. When a body is thus accelerated or retarded, the velocity acquired or loſt will be as the time of its motion, and the ſpace deſcribed as the ſquare of that time or velocity.

75. The ſpace deſcribed will be half that which would be deſcribed in the ſame time by the laſt or firſt velocity continued uniformly.

76. The ſpaces deſcribed in equal ſucceſſive parts of this time taken from the beginning or end of the motion, are as the odd numbers 1, 3, 5. *&c.*

77. The heights of buildings, depths of wells &c. may be meaſured by obſerving the time in which a body falls through them.

78. The velocity, which a body acquires by falling from any height, will carry it again to the ſame height.

79. It always gains the ſame velocity by falling from the ſame perpendicular height, whether it falls freely, or along inclined planes, or curves of any kind.

80. Let any number of chords be drawn in a circle, from the end of that diameter which is perpendicular to the horizon, and the time of deſcent through them all ſhall be equal.

81. The manner in which a cycloid is generated.

82. A difficulty mentioned by *Ariſtotle* concerning the motion of a great and ſmall wheel upon the ſame axis.

83. The manner of meaſuring roads by a wheel.

84. A cycloid is the line, in which a body will ſooneſt fall from one point to another not directly below it.

85. An heavy body may be made to move in a cycloid, by hanging it between two cycloidal cheeks.

86. The ſpace, through which a body will fall in the time of one oſcillation in a cycloid, is to half the length of the ſtring, in the duplicate ratio of the periphery of a circle, to the diameter.

87. All the oſcillations of a body in the ſame cycloid are performed in the ſame time.

88.

88. This time is equal to that, in which a pendulum of the ſame length oſcillates in very ſmall arcs of a circle, but widely different from that, in which a body would oſcillate in any chords of the ſame circle.

89. The times, in which pendulums, whoſe lengths are different, perform their oſcillations, are in a ſubduplicate ratio of thoſe lengths.

90. The manner, in which clocks are regulated by pendulums.

91. Hence we may know, how much the lengths of their pendulums muſt be altered in order to correct them when they go wrong.

92. The errors obſerved in clocks, carried into different latitudes, ariſe from variations, both in the length of the pendulum and in the force of gravity.

93. How much the length of a pendulum is altered by any degree of heat, can only be known by experiments.

94. By an inſtrument for this purpoſe the length of a bar of metal may be very exactly meaſured, and found to be preſently altered by the warmth of the hand.

95. When the force of gravity varies, the lengths of pendulums, that oſcillate in the ſame time, are directly as that force.

96. By the length of a pendulum is always to be underſtood the diſtance between the point of ſuſpenſion and the center of oſcillation.

97. When the pendulum is a cylinder, the diſtance between theſe points is $\frac{2}{3}$ of its length.

98. Bodies of all kinds, when made into pendulums of the ſame length, perform their oſcillations in times exactly equal.

99. A body, thrown in any direction not perpendicular to the horizon, deſcribes a parabola.

100. The horizontal range of a project is as the ſine, and the height to which it riſes, as the verſed ſine, of double the angle of elevation.

101. The greateſt horizontal diſtance equals twice the ſpace, through which the body muſt have fallen to gain the velocity, with which it was projected.

102. Suppoſing the motion of the earth, a body thrown in a direction perpendicular to the horizon deſcribes a parabola;

103. But muſt appear to us to move in a right line.

104. If a body move in a curve, it is continually acted upon by ſome force, and this is called a centripetal force.

105. The endeavour of the body to recede in the oppoſite direction, in conſequence of the firſt law of motion, is called a centrifugal force.

106. If the centripetal force tends conſtantly to the ſame point, the areas deſcribed round that point will be proportional to the times.

107. When bodies deſcribe different circles with an equable velocity, the accelerating forces tend to the centers of thoſe circles, and are as the ſemidiameters of the circles directly, and the ſquares of the periodic times inverſly.

108. From this general rule, whenever it is known what is the ratio of the periodic times at different diſtances, it may be alſo known what is the ratio of the forces, and vice verſa.

109. If the vis motrix, and not the vis acceleratrix is to be eſtimated, to the former ratios that of the quantities of matter muſt be added.

110. The centrifugal force, ariſing from the earth's revolution about its axis, muſt cauſe the ocean to aſſume a ſpheroidical figure.

111. The degrees of latitude are ſhorter near the æquator, than near the poles.

112. Though the centrifugal force of bodies increaſes as their quantity of matter, yet, ſuppoſing the earth in a fluid ſtate, the denſeſt bodies would accede to the center.

113. But ſhould a fluid globe be turned ſo faſt about its axis, that the centrifugal force ſhould exceed that of gravity, the heavier bodies would riſe in it, and the lighter ſink.

114. When unelaſtic bodies meet, and the impact is direct, the velocity of them both after the ſtroke is the ſame, and in the ſame direction.

115. Let the two bodies be A and B, and let the motion be eſtimated in the direction of the body A, then as A+B is to A, ſo is the difference between their velocities before the ſtroke, to the velocity gained by B.

116. If one or both the bodies be elaſtic, the motion taken from one, and communicated to the other, is double what it is in hard bodies.

117. Therefore as A+B is to 2A, ſo is the difference of their velocities before the ſtroke, to the velocity gained by B.

118. If there is a row of equal elaſtic bodies contiguous to each other, and at reſt, and an impulſe is made upon the firſt, that and all the following will continue at reſt, except the laſt, which will move away with the velocity which the firſt would have had, had it been alone.

119. If there is a row of ſuch bodies continually decreaſing in magnitude, they will all move in the direction of the impulſe, and every one with a velocity greater, than that of the preceding.

120. If there is a row of ſuch bodies continually increaſing in magnitude, they will all move in a direction oppoſite to that of the impulſe, except the laſt, whoſe motion will be equal to that, which the impulſe would have produced in it, added to the ſum of the motions of the preceding bodies.

121. The diſpute between the Carteſians and modern Philoſophers, whether the quantity of motion in the world is ever changed, may be thus determined: if we conſider motion in all directions, it perpetually varies; but if we eſtimate the motion in one direction only, and call the oppoſite motion negative, we know of no powers in nature, which can change its quantity.

122. Various experiments have been made with bodies falling into ſoft clay, or upon the arms

arms of a balance, or moved by ſprings, to ſhew that the force of bodies in motion is proportional to the ſquare of their velocities.

123. Moſt of theſe experiments ſucceed as they are deſcribed;

124. But they do not prove the point they are brought to prove:

125. Nor can the queſtion be ever determined by experiments.

ASTRO-

ASTRONOMY.

1. THE principles of Aſtronomy cannot be proved by experiments, properly ſo called.

2. But ſome of the appearances in the heavens, and the reaſons of them, may be illuſtrated by machines contrived for that purpoſe.

3. The different ſyſtems of the world explained.

4. The order, diſtances, magnitudes, and periodic times of the primary planets, according to the Copernican Syſtem.

5. Conjectures concerning the diſtances and magnitudes of the fixed ſtars.

6. The diviſions of the ecliptic and other circles.

7. The apparent diurnal rotation of the heavens muſt be the ſame, whether they really move round the earth, or the earth turns in the ſame time about its own axis.

8. The apparent annual motion of the ſun muſt be the ſame, whether the ſun goes about the earth, or the earth about the ſun.

9. Reaſons to believe, that both theſe motions are in the earth.

10. To find the place of the earth in its orbit, or the apparent place of the ſun at any time of the year.

11. The earth's motion in it's orbit is not equable.

12. But it deſcribes about the ſun areas proportional to the times.

13. The earth is neareſt to the ſun in the midſt of winter.

14. The earth's axis is inclined to the plane of its orbit.

15. To find the length of the day or night in any part of the earth at any time of the year.

16. The various paths, which the ſun ſeems to deſcribe above the horizon to thoſe, who live in a right, oblique, or parallel ſphere.

17. The riſings and ſettings of the fixt ſtars which are called coſmical, acronychal, and heliacal.

18. An eaſy method of drawing a ſun-dial upon any given plane.

19. The ſtyle of every dial muſt be parallel to the axis of the earth.

20. The ſhadow upon a dial may go backwards in ſome places upon the earth's ſurface.

21. Time, as meaſured by the ſun's motion, does not flow equably.

22. The methods of finding when an inſtrument, which meaſures time exactly, goes before or after the ſun.

23. Several methods of finding the latitude of a place.

24. An explanation of a paradox, which aſſerts, that of two places A and B, if A is eaſt of B, it does not follow, that B is weſt of A.

25. A method of finding the longitude of any place upon land.

26. The difficulty of diſcovering it at ſea, with an account of the principal methods, in which it has been attempted.

27. The præceſſion of the æquinoxes explained.

28. The ſun turns about its axis.

29. The inferior planets can never appear ninety degrees diſtant from the ſun.

30. They have two different conjunctions with him.

31. When Venus is ſeen in the morning, and when in the evening.

32. The ſuperior planets may have any angular diſtance from the ſun.

33. In what ſituation the planets are ſtationary, when they move forward, or according to the order of the ſigns, and when backward or contrary to that order.

34. Their latitudes, as ſeen at the ſun, and at the earth.

35. The method of diſcovering the proportion of the earth's diſtance from the ſun, to the diſtances of the planets.

36. The method of finding their periodic times.

37. The ſquares of their periodic times are, as the cubes of their diſtances from the ſun.

38. It is probable, that every planet turns about an axis.

39. Comets are a kind of primary planets moving in very excentric orbits.

40. More are ſeen in the hemiſphere next the ſun, than in the oppoſite.

41. The courſe of ſome of them is from weſt to eaſt, of others from eaſt to weſt, and their orbits are differently inclined to the ecliptic.

42. Hence it appears, that the planets are not moved in their orbits by vortices.

43. Of the ſecondary planets one goes round the Earth, four round Jupiter, and five round Saturn.

44. The different phaſes of the moon explained.

45. The moon's diſtance from the earth and magnitude.

46. The difference between a ſynodical and periodical month.

47. The periodical month is exactly equal to the time, in which the moon turns about its axis.

48. Therefore the ſame ſide of the moon is conſtantly towards the earth.

49. The inclination of the moon's orbit, and the motion of its nodes.

50. The tides are raiſed by the moon twice in about 25 hours;

51. And are at their greateſt height about three hours after the moon has paſſed the zenith, or nadir of the place.

52. The difference between ſpring and neap tides.

53. In ſummer the tides raiſed by the moon, when above the horizon, generally exceed thoſe raiſed by her, when below it; the contrary happens in winter.

54. The ſatellites of Jupiter and Saturn appear to move from weſt to eaſt, and from eaſt to weſt by turns.

55. The appearances of Saturn's ring explained.

56. All the ſatellites eclipſe, and are eclipſed by the primary planets, to which they belong.

57. To determine the ſhape of the ſhadow and penumbra, when a luminous globe ſhines upon an opake one.

58. To determine when there will be an eclipſe of the moon, and whether it will be total or partial.

59. To determine the ſame things concerning an eclipſe of the ſun.

HYDROSTATICS
AND
PNEUMATICS.

1. THE denſity and ſpecific gravity of a body is proportional to the quantity of matter contained in it, when the bulk is given.

2. The parts of fluids are heavy, and by their weight preſs both upon other bodies, and upon one another.

3. The weight of any quantity of a fluid is the ſame within a fluid of its own kind, as in vacuo.

4. All the particles of a fluid at reſt preſs equally in all directions.

5. If the ſides of a veſſel are perpendicular to the bottom and to the horizon, the preſſure of a fluid upon the bottom is equal to its weight.

6. In other caſes it may be greater or leſs.

7. Therefore by altering the form of the veſſel any quantities of a fluid, however unequal, may be made to preſs equally upon the bottom.

8. But yet theſe veſſels will not preſs equally upon what is below them, or be equally heavy.

9. For where the veſſel is narrower at the top, part of the weight is taken off by the preſſure upwards.

10. The preſſure upwards of a ſmall quantity of water may be ſo great, as to raiſe a weight of ſeveral hundred pounds.

11. The Preſſure upon any part of the bottom or ſide is, as the area of that part, the perpendicular height of the fluid above it, and its ſpecific gravity.

12. When the preſſure of a fluid, upon one ſide of the veſſel containing it, is in part removed, the effect of the oppoſite preſſure is immediately perceived.

13. The perpendicular heights of fluids, contained in veſſels communicating with each other, are reciprocally, as their ſpecific gravities.

14. A ſolid, immerſed in a fluid of the ſame ſpecific gravity, will continue at reſt, where-ever it is placed.

15. If the weight of the ſolid be greater or leſs, than the weight of a quantity of fluid equal to it in bulk, it will deſcend or aſcend with a force equal to the difference of thoſe weights.

16. The aſcent of a body in a fluid ſpecifically heavier is owing to the preſſure of the fluid upwards.

17. When this preſſure is taken off, the body will not aſcend.

18. This preſſure may be ſo great as to ſuſtain a body, whoſe ſpecific gravity has any aſſignable ratio to that of the fluid, provided the preſſure downwards be taken off.

19. The part of its weight, which a body loſes by being immerſed, is to the whole, as the ſpecific gravity of the fluid, to that of the ſolid.

20. This part is communicated to the fluid.

21. The opinion of Mr. Leibnitz, that a fluid with a ſolid immerſed weighs leſs, while the ſolid

is

is falling, than when it is ſuſtained, is either true or falſe, according to the different manners, in which the ſolid may fall or be ſuſtained.

22. When a body floats, the part immerſed is to the whole, as the ſpecific gravity of the ſolid, to that of the fluid.

23. Several kinds of hydrometers are made upon this principle.

24. The greateſt burthen of a ſhip may be found from knowing its bulk.

25. A method of raiſing great weights from the bottom of the ſea.

26. By weighing a ſolid both in vacuo, and in a fluid, the proportion of a ſpecific gravities of that ſolid and fluid may be known.

27. By weighing ſeveral ſolids in the ſame fluid, the proportion of their ſpecific gravities may be known.

28. As alſo that of ſeveral fluids, by weighing the ſame ſolid in them.

29. The velocity, with which a fluid will ſpout from an hole in a veſſel, may be found experimentally, either by obſerving the parabola it deſcribes, or the quantity flowing out in a given time.

30. By the former method the velocity appears to be that, which an heavy body acquires by falling the whole height of the fluid above the hole.

31. By the latter that, which is acquired by falling only half the height.

32. The reaſon of this difference.

33. When a fluid iſſues from the ſide of a veſſel in a line parallel to the horizon, it will fall upon an horizontal plane, paſſing through the bottom of the veſſel, at the greateſt diſtance, if the hole is in the middle of the veſſel's height.

34. And it will fall upon the ſame part of that plane from two holes, equally diſtant from the top and bottom of the veſſel.

35. When a fluid ſpouts directly upwards, it riſes nearly to the height of the ſurface of the ſtagnant fluid.

36. The cauſes which prevent its riſing exactly to that height.

37. The height and the diſtance, to which a fluid ſpouts, in all the different elevations of the jet, may be determined by the rules concerning projectiles.

38. The velocity of a fluid iſſuing at holes of different depths, and the quantity coming out in a given time are in a ſubduplicate ratio of the depths.

39. The velocity of a fluid, iſſuing at a hole in the bottom or ſide of a cylinder, is uniformly retarded.

40. The manner of meaſuring time by water, running out of a veſſel.

41. The reſiſtance, which a body ſuffers by moving through a fluid, is equal to the force, with which a ſtream of that fluid acts upon the body, when it falls againſt it with the ſame velocity.

42. This force is as the ſquare of the velocity.

43. And if the body be a globe, as the ſquare of its diameter.

44. When bodies of the ſame weight begin to move through a fluid with the ſame velocity, that, which has the greateſt magnitude, will ſooneſt loſe its motion.

45. When bodies of the ſame magnitude begin to move through a fluid with the ſame velocity, that which has the leaſt weight, will ſooneſt loſe its motion.

46. Another kind of reſiſtance in fluids ariſes from their tenacity.

47. The air is an elaſtic fluid, or one, whoſe dimenſions are increaſed by diminiſhing the preſſure upon it, and diminiſhed by increaſing the preſſure.

48. Its denſity is always as the compreſſing force.

49. Air may be made to expand itſelf, till it takes up 1000 or 10000 times the ſpace it ordinarily poſſeſſes; and how much farther it is capable of being rarified, is not yet diſcovered.

50. There is air contained in the pores of moſt bodies, which, when the external preſſure is removed, expands itſelf and produces various appearances.

51. Air may be reduced to a third or fourth part of its uſual dimenſions; and how much farther it might be condenſed cannot be known, becauſe its force ſoon becomes ſo great, as to burſt the ſtrongeſt veſſels.

52. Condenſed air has various effects upon bodies placed within it.

53. The air is heavy, and its weight produces juſt the ſame effects, as its elaſtic force.

54. Its weight is able to ſuſtain a Column of mercury, whoſe perpendicular height is about 30 inches.

55. When the quantity of air, preſſing upon the ſtagnant mercury, is leſſened, that in the barometer ſinks; when increaſed, it riſes.

56. Several methods have been taken to make ſmall changes in the height of the mercury the more eaſily perceived, as inclining the tube, adding a wheel to it &c.

57. The height of a column of any other fluid, which is ſuſtained by the preſſure of the air, is to that of mercury, as the ſpecific gravity of mercury, to that of the fluid.

58. The aſcent of water in various kinds of ſyphons and pumps is owing to this preſſure of the atmoſphere.

59. But in all engines, which raiſe water, as much force is exerted in working them, as would be ſufficient to lift the ſame quantity of water to the ſame height.

60. In common ſyphons the fluid is always conveyed from an higher place to a lower.

61. A ſyphon may be ſo contrived, that part of the fluid ſhall be conveyed to an higher place.

62. But to effect this, there muſt be at leaſt as much motion of another part of the fluid downwards.

63. And this rule is general with regard to all machines, which are moved by a fall of water, and employed to raiſe it.

64.

64. In engines made to extinguiſh fires, a continual ſtream of water is forced out by the ſpring of the included air.

65. Fountains of ſeveral ſorts are made by the weight and elaſtic force of the air.

66. It is eaſy to find the weight of a column of the atmoſphere, whoſe baſe is given.

67. That which preſſes upon a man's body exceeds 30000 pounds.

68. A force which appears to be very great, when it acts only in one direction, will not affect the moſt tender ſubſtances, if it acts equally on all ſides.

69. The nature of the diving-bell explained.

70. Freſh air may be conveyed to it, whenever a veſſel can be let down to a greater depth than the bell.

71. The rarified air may be let out.

72. The manner of meaſuring the depth of the ſea, where it exceeds the length of any lines, which can be procured.

73. When the air in any place is rarified by the removal of any part of it, the denſer air will preſs into that place.

74. But this will not happen, when the air is rarified by heat only.

75. The manner, in which winds are produced.

76. Eſpecially thoſe, which blow between the tropics.

77. The manner, in which vapours are raiſed, and dew or rain formed.

78. Smoke and other light bodies, which aſcend in the air, fall again in an exhauſted receiver.

79. Reſpiration and ſuccion are performed by the help of the air's preſſure.

80. The death of animals in an exhauſted receiver, is not owing to the preſſure of the air included in their bodies upon their lungs.

81. Air, filled with ſuch ſulphureous vapours as are prejudicial to animals, will alſo extinguiſh flame.

82. Air is neceſſary for preſerving fire.

83. Even gunpowder will not catch fire in vacuo.

84. On the contrary, ſeveral kinds of phoſphorus ſhine moſt in an exhauſted receiver.

85. Quickſilver ſhaken in a veſſel, from which part of the air is drawn, becomes luminous.

86. The moiſture or dryneſs of the air is diſcoverable by ſeveral kinds of inſtruments.

87. The heat or cold of it by others.

88. A ſmall degree of heat will make water boil, when the preſſure of the atmoſphere is removed.

89. All violent agitations of the ſmall particles of bodies produce heat.

90. Sound ariſes from a tremulous motion of the particles of the ſounding body.

91. This motion is propagated by the air.

92. The ſound of a bell included in a receiver becomes gradually weaker, as the air is drawn out, till it is intirely loſt.

93. By placing the bell in condenſed air, the ſound is made more intenſe.

94. When very ſmall glaſs tubes are dipt into water, the attraction of the glaſs will raiſe the water,

ter, and ſuſpend it at an height, which is inverſly, as the diameter of the tube.

95. And if two ſuch tubes, communicating with each other, are in part filled with water, its ſurface will be higher in the leſs tube.

96. The particles of mercury attract each other with more force, than they are attracted by glaſs.

97. And therefore in ſmall glaſs tubes, communicating with each other, the ſurface of the mercury will be lower in the leſs tube.

98. If a tube be dipt into water ſo far, that its height above the ſurface is leſs, than the height, to which the attraction can raiſe it, yet the water will not flow over the top.

99. When a tube is filled with water and not dipt, the length of the column ſuſpended is ſomewhat greater, than when one end of it is under water.

100. The attraction, with which the parts of water act upon each other, occaſions this difference.

101. The perpendicular height of the water is the ſame, if the tube is inclined.

102. The upper ſurface is in this caſe circular.

103. Let the tube be taken out of the water and laid parallel to the horizon, then the fluid will recede from the end which was dipt, if the tube is cylindrical, only a little way; but if conical, to its vertex.

104. This motion of the water in a conical tube is not owing to any advantage, with which the ſmaller end of the tube acts upon it, but to the direction, in which every part of the glaſs attracts it.

105.

105. If a capillary ſyphon be filled with water and not immerſed, the water will not flow out of the longer leg, unleſs the difference of the legs exceeds the height, to which the ſhorter can raiſe it.

106. But if the ſhorter leg is immerſed, it will run as through a larger ſyphon.

107. When the tube is compoſed of two parts, whoſe diameters are different, the height of the water ſuſpended is the ſame, as if the tube had every where that diameter, which it has at the upper ſurface.

108. This experiment will not ſucceed, unleſs the parts of the tube are joined in ſuch a manner, as to exclude the preſſure of the air.

109. The weight ſuſtained by the glaſs is exactly the ſame, as in the ſimple tube, the preſſure of the air ſupporting the reſt of the water, when the tube is larger at the bottom; and adding to the weight, when it is leſs.

110. No objection to this account can be drawn from the ſucceſs of the common experiments in an exhauſted receiver.

OPTICS.

OPTICS.

1. LIGHT conſiſts of ſmall and diſtinct particles, which are ſubject to the ſame laws as other bodies.

2. It is continually emitted from luminous ſubſtances in right lines.

3. But may be turned out of its ſtraight courſe by the action of other bodies upon it.

4. Its motion is moſt affected by thoſe bodies, upon which it acts moſt ſtrongly.

5. The methods of finding the velocity of light explained.

6. The ſhape of ſhadows may be determined by conſidering, that light always moves in right lines.

7. And by their lengths the heights of buildings &c. may be found.

8. The rays of light are bent, when they paſs by the edges of bodies, and thoſe rays are moſt bent, which paſs at the leaſt diſtance.

9. When light is turned back by reflection, the angle of reflection lies in the ſame plane with, and is equal to the angle of incidence.

10. Hence we have another method of taking heights.

11. When light enters a denſer medium, it is refracted towards the perpendicular; when a rarer, from it.

12. The angle of refraction lies in the ſame plane with, and its ſine is in a given ratio to that of the angle of incidence.

13. When light paſſes out of air into water, the ſines of incidence and refraction are to each other, nearly as 4 and 3; when into glaſs, as 3 and 2.

14. The refraction of the atmoſphere raiſes the apparent places of all the heavenly bodies, which are not in the vertex.

15. And makes the ſun and moon, when near the horizon, appear oval.

16. Parallel rays, reflected or refracted by one or more plane ſurfaces, continue parallel.

17. When converging or diverging rays fall upon any plane ſurface, they continue to converge or diverge.

18. And the diſtance of the focus from the ſurface is, to the diſtance of the focus of incident rays, as the ſine of incidence, to that of reflection or refraction.

19. Parallel rays falling upon a ſpherical ſurface are made to converge or diverge.

20. When they are reflected, or refracted into a denſer medium, the focus lies on the concave ſide of the ſurface; when they are refracted into a rarer, on the convex.

21. In all theſe caſes the diſtance of the focus from the ſurface is to its diſtance from the center, as the ſine of incidence, to that of reflection or refraction.

22. Whenever the place of the principal focus is known, the focus of diverging or converging rays may be thus found: the diſtances of the principal focus from the focus of incident rays, from the center, and from the focus of refracted or reflected rays are in continual proportion.

23. Hence the focus of all lenſes may be found.

24. Refracting ſurfaces having two principal focuſes, in the two firſt terms of this proportion the focus of rays coming the contrary way is to be taken; in the two laſt, the other.

25. By the center is meant the point, through which, if a ray paſſes, it is either not turned out of its ſtraight courſe, or returns into it again.

26. When the rays are reflected, if the focus of incident rays moves, that of the reflected rays moves in the contrary direction, and they meet at the center and at the ſurface.

27. When they are refracted, the two focuſes move in the ſame direction.

28. Theſe rules relate principally to a pencil, whoſe axis coincides with that of the glaſs, but they are very nearly true of others, when the inclination is not great.

29. Where the rays of each pencil are united, a diſtinct image will be formed.

30. An image may ſerve inſtead of an object, and thus a ſecond image will be formed, which will occaſion a third, that a fourth, &c.

31. When an object is placed between two plane ſpecula parallel to each other, there is formed by each ſpeculum a row of images, which as they are more remote are gradually fainter, till they become inviſible.

32. When the two ſpecula are inclined to each other, as many images are formed by them, as there are angles, equal to that contained between them, in its compliment to four right angles.

33. The linear magnitude of the image is to that of the object, as its diſtance from the center, to that of the object.

34. It is erect, when it is on the ſame ſide of the center, with its object; inverted, when on the other.

35. From hence may be ſeen the reaſon of all the appearances, in the magic-lantern, and in all the various kinds of the camera obſcura.

36. The uſe, of what is called the ſolar microſcope, depends upon the ſame principles.

37. The pictures of ſmall objects may be magnified by this inſtrument many thouſand times, and yet continue diſtinct.

38. The ſun's image is formed in the focus of a glaſs, expoſed to the ſun's rays.

39. In the focus of ſome glaſſes the heat is more violent, than any other that is known.

40. By obſerving the breadths of the glaſſes, and the diſtances of their focuſes, the denſity of the rays in their ſeveral burning ſpots may be compared with each other, or with the denſity of the ſun's direct rays.

41. When rays of light enter our eyes, they are refracted by the humours, and form images of the objects they come from.

42. If they are well formed, or the rays of each pencil exactly united at the bottom of the eye, viſion is diſtinct.

43. This could only happen when the objects were at one certain diſtance, if the ſhape of the eye and the ſituation of it's humours were conſtantly the ſame.

44. The changes, which might be made in the eye ſo as to render the picture diſtinct, while the diſtance of the object varies, may be ſeen in an artificial eye.

45. The defects of ſuch eyes, as unite the rays either before the retina or beyond it, may be remedied by glaſſes.

46. Short-ſighted perſons can ſee diſtant objects beſt, when they are ſtrongly illuminated;

47. But can ſee near objects with leſs light, than they who have perfect eyes.

48. The reaſon, why the inferior planets appear to the naked eye conſtantly round, though by a teleſcope they are found to have the ſame variety in their phaſes, as the moon.

49. The breadth of the picture at the bottom of the eye is reciprocally, as the diſtance of the object.

50. The picture is nearly of the ſame brightneſs at all diſtances of the object.

51. We are able to ſee by quantities of light exceedingly different.

52. Common day-light exceeds the light of the full moon at leaſt 90000 times.

53. In looking with one eye at any broad object, placed directly before us, a part of it is not viſible.

54. Habit prevents this from being commonly obſerved.

55. It is from habit, that we imagine an object, ſeen with both eyes, to be ſingle or double.

56. It is habit alſo, which enables us to judge of diſtances by ſight.

57. Our judgments of the diſtance and the magnitude of an object are generally connected.

58. Neither the divergency of the rays coming from the ſame point of an object, nor its diſtinctneſs, nor brightneſs, nor the angle between the optic axes, nor the interval between the pupils uſually ſuggeſts to us the diſtance.

59. The apparent magnitude of an object ſeen either by the naked eye or with glaſſes, is meaſured by the angle, which the rays coming from the extremities of it make, when they fall upon the eye.

60. Hence the general principles of perſpective may be explained.

61. And a method may be found of drawing deformed pictures, which appear to have juſt proportions, to an eye in one ſituation.

62. When an object is ſeen erect through a convex lens or in a concave ſpeculum, the apparent magnitude is always either equal to or greater than its magnitude to the naked eye.

63. When it is ſeen through a concave lens or in a convex ſpeculum, the apparent magnitude is either equal to or leſs than the true.

64. If an object be ſo placed before a cylindrical reflecting ſurface, that one diameter is parallel to the axis of the cylinder, that diameter will appear of its juſt length; all the others will be increaſed, if the ſurface is concave; diminiſhed, if it is convex.

65. Hence may be found the method of drawing deformed pictures, which will appear regular in a cylinder, placed on the plane of the draught.

66.

66. A piece of perſpective may be ſo placed before a concave ſpeculum, that it ſhall appear larger and more projected, than when it is ſeen by direct rays.

67. It is ſeen with the ſame advantages through a convex lens.

68. The part of a fixt object, ſeen in a given part of a glaſs, is greateſt, when the eye is cloſe to the glaſs; leaſt, when it is cloſe to the image.

69. In a plane ſpeculum a man ſees an equal part of his own body at all diſtances, and the length and breadth of this part are half thoſe of the glaſs.

70. Several kinds of teleſcopes may be formed by combinations of ſpecula and lenſes.

71. The glaſſes muſt be ſo placed, that the rays of the ſame pencil may be nearly parallel, when they fall upon the eye.

72. In all kinds of teleſcopes, which have only one eye-glaſs, the apparent magnitude is to the true, as the focal length of the object-glaſs, to that of the eye-glaſs.

73. When more glaſſes are added, whoſe focal lengths are equal, the apparent magnitude continues the ſame.

74. The magnifying power of a teleſcope may be increaſed either by increaſing the focal length of the object-glaſs, or by diminiſhing that of the eye-glaſs.

75. But if the proportion of their focal lengths is too great, the object becomes indiſtinct.

76. A concave reflecter will bear a much ſhorter focus without confuſion, than a lens of the ſame focal length.

77. When we uſe one convex eye glaſs, the object is inverted; but it is erect, when we uſe one concave, or three convex eye glaſſes.

78. The viſible area is much ſmaller, when the eye glaſs is concave, than when it is convex.

79. The proper diſtance of the eye from the firſt glaſs, if it is convex, equals its focal length; but if it is concave, the eye ſhould be as near it as poſſible.

80. Any tranſparent globe or lens, whoſe focal length is very ſmall, will ſerve for a microſcope.

81. The apparent magnitude of an object, ſeen in ſuch a microſcope, is to its true magnitude, when ſeen diſtinctly by the naked eye, as the leaſt diſtance, at which it can be thus ſeen, to the focal length of the glaſs.

82. In a microſcope formed of two lenſes, the linear magnitude of the image exceeds that of the object, in proportion as its diſtance from the firſt glaſs exceeds the diſtance of the object: and this image is again magnified, as in a ſingle microſcope.

83. In a ſingle microſcope, the apparent ſituation of the object is not altered; in a double one, it is inverted.

84. The light of the ſun or of any luminous body conſiſts of rays, which differ in colour.

85. Theſe colours are not changed by reflection or refraction.

86.

86. Bodies of any ſtrong colour reflect the rays of that colour moſt copiouſly.

87. By a mixture of rays of two or more colours, one may be produced different from all thoſe which compoſe it.

88. Theſe rays may be again ſeparated, and each ſort will retain its original colour.

89. The whiteneſs of the ſun's light is compounded of all the primary colours.

90. Whiteneſs may ariſe from rays of different colours, which enter the eye ſeparately, if the intervals between them are ſufficiently ſmall.

91. The rays, which differ in colour, differ alſo in degree of refrangibility.

92. The rays, which are more refrangible, than others, are alſo more reflexible.

93. Reflection of light is not cauſed by its impinging upon the ſolid parts of bodies.

94. The tranſparency of bodies ſeems to ariſe from their having ſmall pores, equably diſtributed.

95. The rays of light are by turns more eaſily refracted and reflected.

96. The refraction of Iceland Cryſtal explained.

97. The primary rainbow is cauſed by two refractions and one reflection of the ſun's light in drops of water.

98. The rays, by which it is ſeen are thoſe, which make the greateſt angle with the incident rays, when they come from the drop.

99. The colours lie in the ſame order, as in the ſun's image formed by a priſm; that of the moſt refrangible rays being on the inner ſide.

100. The ſecondary rainbow is cauſed by rays twice reflected and twice refracted.

101. The rays by which it is ſeen are thoſe, which, when they come out of the drop, make the leaſt angle with the incident rays.

102. The order of the colours is contrary to that in the primary rainbow.

103. The ſecondary rainbow is fainter than the primary, and leſs frequently ſeen.

104. The Moon upon the ſame Principles as the ſun produces a Rainbow.

FINIS.